

EXAMPLES OF DISTRIBUTIONS OF HARD PAVED RUNWAY SURFACE TYPES

1. NOTATION AND UNITS

		<i>SI</i>	<i>British</i>
d_{tex}	texture depth of runway surface, see Section 3.1	mm	in
l_r	length of runway*	m	ft
N_g	number of grooved runways in sample		
N_{pfc}	number of Porous Friction Course runways in sample		
N_r	number of runways in sample		
w_r	width of runway*	m	ft
$\phi(d_{tex})$	cumulative probability density of d_{tex}		

* The units quoted for l_r and w_r are those used by each country in References 6 and 8.

2. INTRODUCTION

This Data Item presents examples of distributions of runway surface types so as to provide a background for the selection of tyre friction data in Data Item No. 71026, Reference 2, (and, indirectly, in Data Item No. 86016, Reference 3) appropriate to typical hard paved runway surfaces.

Two kinds of data are provided; those based on “texture depth” measurements of runway surfaces – see Section 3, and those based on information provided in the “Aeronautical Information Publications” of individual countries – see Section 4. Table 3.1 provides a key to all of the “Figures” giving the distributions – which, from Figure 3a onwards, are arranged in order of country-of-origin so as to facilitate the addition of more examples.

No information is given for individual runways. It is emphasised also that published information about a runway can only be regarded as reliable if the runway is subject to a continuous program of inspection, monitoring, cleaning and maintenance.

3. DISTRIBUTIONS OF RUNWAY SURFACE TYPES BASED ON TEXTURE DEPTH MEASUREMENTS

3.1 Surface Macro-Texture Depth*

Surface macro-texture is one factor (among many) that influences tyre-runway friction (see Reference 1). The magnitude of the surface macro-texture depends on the sizes and relative quantities of the aggregates used and may be judged approximately by eye. A measure* of surface macro-texture depth, d_{tex} , can be obtained by working a known volume of grease into the surface voids until a smooth finish is obtained (sand was used for some early work in the UK). The average texture depth is the ratio of the volume of grease used to the surface area covered.

Reference 2 defines five types of runway surface, A, B, C, D, E based on measurements of the runway surface macro-texture; the ranges of values of texture depth for the five categories are as follows.

TABLE 3.1

Surface type		A	B	C	D	E
Range of values of texture depth	mm	0.1016 to 0.1524	0.1524 to 0.254	0.254 to 0.508	0.508 to 1.016	1.016 to 2.54
	in	0.004 to 0.006	0.006 to 0.01	0.01 to 0.02	0.02 to 0.04	0.04 to 0.1

3.1.1 Macro-texture depth variability due to operator technique and type of equipment

The measurement of runway macro-texture depth is subject to uncertainty – arising from several sources. It is therefore appropriate to warn against the search for undue precision in its measurement or in the inferences drawn in terms of tyre friction.

For example, Reference 21 reports ranges of values of texture depth obtained in a small area of a surface by a number of operators using two types of equipment. Two conclusions may be drawn.

- (i) Results obtained from inexperienced operators contain larger random errors than those obtained from experienced operators.
- (ii) Use of different equipment (grease spreaders) can produce systematic differences which are greater than the operator errors instanced in (i).

The existence of such uncertainty is of particular significance if a single measurement of texture depth is used as the basis for assigning a surface to one of the categories listed in Section 3.1. In cases of doubt, a surface can be taken as the average of two adjacent types from A to E if that more truly reflects the measured value(s).

The variability of texture within the length of a runway is addressed in Section 3.2 and Figure 2.

* The surface macro-texture depth used here is relatively crude. However, it is the only such parameter generally recorded in conjunction with the measurements of tyre-runway friction on which Figures 3 to 15 in Reference 2 are based. Other measures of texture, based on drainage criteria and on photogrammetry, have been developed.

3.2 Examples of Distributions of Runway Texture Depth and Surface Types A, B, C, D, E

Figures 1, 2, 3a, 3b, 4a, 4b, 4c and 5 present cumulative probability distributions, $\phi(d_{tex})$, of runway texture depth. From Reference 4, it follows that the probability of a runway having a given surface from among types A, B, C, D, E is

$$\phi(d_{tex})_{upper} - \phi(d_{tex})_{lower},$$

where subscripts *upper* and *lower* denote the limiting values of texture for the given surface type in Table 3.1.

Figure 1 presents a “datum distribution” which is based on all available runway texture measurements made since 1974. This date is chosen so that the datum reflects modern trends in runway surface construction*. The data used in constructing Figure 1 are for runways in the United States, the United Kingdom and France (Figures 3a, 3b, 4a, 4b, 4c and 5 compare the data from each country with the datum). In the absence of any other data, Figure 1 may be taken as representative of runways in other countries where comparable runway surface construction techniques are employed.

Figure 2 is included here to emphasise the highly-variable nature of texture depth as an indicator of runway friction properties – in this case the variation that can occur within the length of a single runway. Figure 2 illustrates a relatively extreme example of such a variation by presenting the distribution of texture depth as deduced from measurements in clean areas (datum curve) and in heavily rubber-contaminated areas (*i.e.* the touch-down region of runways).

Figures 3a, 3b, 4a, 4b, 4c and 5 provide a limited guide to the cumulative probability distributions of runway texture depth and surface types for individual countries. Each of these Figures includes the datum curve from Figure 1 as a basis of comparison. While it is unfortunate that many of the data used in these Figures are relatively old, they do serve to illustrate the changes in distributions taking place during a period when the subject of runway friction was receiving much attention. Those changes are due to the increasing use of

- (i) mechanical texturing of surfaces, for example “combing”, wire brushing and scoring of concrete, and grooving of asphalt and concrete surfaces,
- (ii) coarse aggregates, notably in the form of the “Porous Friction Course” type of surface.

Since the trends evident in Figures 3a, 3b, 4a and 4b are unlikely to be reversed, it can be concluded that, for those countries at least, surface types A and B are unlikely to be encountered on major civil or military runways. However, this situation can only be *ensured for any given runway* by a continuous program of inspection, monitoring, cleaning and maintenance.

Comments on data for particular countries are given in Section 5.

* The benefits to be obtained from runways having relatively large macro-texture depths were recognised much earlier but implementation on a large scale was not immediate.

4. DISTRIBUTIONS OF GROOVED AND POROUS FRICTION COURSE RUNWAYS BASED ON PUBLISHED AIRPORTS DATA

Figures 3c, 4d, 6, 7 and 8 present distributions of grooved and “Porous Friction Course” runways as functions of runway length and width for a number of countries. For each country up to 16 combinations of runway lengths and widths are considered and values given for:

- the number of runways, N_r ,
- the number of grooved runways, N_g ,
- the number of Porous Friction Course runways, N_{pfc} ,
- the proportion of grooved or porous runways, expressed as a percentage, *i.e.*
 $[(N_g + N_{pfc})/N_r] \times 100$.

These data have been taken from among the wide range of information issued in the *Aeronautical Information Publications* (AIPs), or equivalent, for the relevant countries – References 6 and 8. The units quoted for runway dimensions in the figures are those used by each country in References 6 and 8. The ranges of lengths and widths used to categorise the runways are “rounded” values for each units system and not exact conversions.

Where available, data are given for the widest possible range of runways, including those designated (in References 7, 8) as

AGA – 2*: Airports used by international commercial air transports.

AGA – 3*: Any other aerodromes (for example, “Licensed Aerodromes” in UK).

While the surface definitions “grooved” and “Porous Friction Course” do not directly correspond with the categories defined in Section 3.1, most of the runways will be of types D or E (see Figures 2a, 2c in Reference 2). In exceptional cases, such as runways with very shallow or very widely-spaced grooves, the surface might be of type C.

Data are only presented for those countries for which it is believed the information is reasonably complete. In using the figures it is advisable to consider the number of runways involved as well as the quoted percentages of grooved and porous surfaces. In some cases the number of runways involved is so small that no percentage values are quoted.

* “Aerodromes, Air Routes and Ground Aids”.

5. USE OF AND COMMENTS ON THE DATA

If the coefficient of friction data from Reference 2 are to be used in the calculation of aircraft field lengths for operations on wet runways, a conservative approach should be adopted in the first instance, and data for Surface B or C (or a combination thereof) selected. The present Data Item provides a limited basis for deciding if the distribution of runways in a country is such as to justify the calculation of performance for additional surface types.

Data based on actual measurements of runway surface texture were available for the USA, UK and, to a limited extent, France. Most of those data are relatively old. Information regarding the existence of grooved or Porous Friction Course surfaces in *Aeronautical Information Publications*, or equivalent, was available for: USA, UK, Japan, Australia and Switzerland.

Figures 3c, 4d, 6, 7 and 8 adopt a subdivision of runways into those that have grooved or Porous Friction Course surfaces and those that do not*. This subdivision is arbitrary, but has achieved a measure of acceptance in the United States. The effect of applying this subdivision to a set of runway surface texture measurements is illustrated in Figure 4b.

From Figures 3c, 4d, 6, 7 and 8 it can be concluded that, in general†, runways with $l_r < 6000$ ft (1800 m) and $w_r < 80$ ft (25 m) are unlikely to have grooved or Porous Friction Course surfaces.

In the United States, the relatively high proportion of surface types D and E in Figure 3a reflects the extensive use of runway grooving (and Porous Friction Courses) even in 1975. The different curves in Figure 3b illustrate the changes in surface texture distributions due to changing construction practices. The data in Figure 3c suggest that for large transport aircraft, operating from runways with $l_r > 8000$ ft, a very considerable proportion of those runways have grooved or Porous Friction Course surfaces. These data are taken from References 6, the U.S. equivalent to the AIP.

In the United Kingdom, the data in Figure 4a suggest that most international air transport operations are from runways of types C, D or E. From Reference 20 (and, by inference, from Figure 4d), a considerable proportion of those type C, D or E runways have neither grooved nor Porous Friction Course surfaces. The shape of the “lower” end of the curve for grooved and Porous Friction Course surfaces in Figure 4b corresponds to limited usage of relatively shallow grooving in the United Kingdom.

In France, the proportion of type D surfaces shown in Figure 5 may have been influenced by the fact that one of the three References used was devoted to the study of grooved runways – most of which had relatively large spacings between the grooves.

In Japan, the high proportion of grooved runways is deduced from the AIP; no Porous Friction Course surfaces are identified.

Australia and Switzerland are the only other countries for which significant evidence of grooved or Porous Friction Course surfaces can be found in the current issues of their AIPs. For both countries the number of runways concerned is small and so the percentages of such surfaces are not quoted in Figures 7 and 8.

* Other types of surface may yield large texture depth values and good friction properties in wet conditions, see Figure 2 in Reference 2.

† The data for runways in the Northwest Region of the United States provide an exception insofar as 24% of those runways with $70 \leq w_r \leq 80$ ft had grooved or porous surfaces (Reference 6).

6. REFERENCES

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